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THE ORIENTED SCINTILLATION SPECTROMETER EXPERIMENT (OSSE) INSTRUMENT DESCRIPTION

1989

W. N. Johnson[1], J. D. Kurfess[1], R. L. Kinzer[1], W. R. Purcell[2],
M. S. Strickman[1], G. V. Jung[3], M. P. Ulmer[2], C. M. Jensen[4],
G. H. Share[1], D. D. Clayton[5], C. S. Dyer[6], R. A. Cameron[3]

ABSTRACT

The Oriented Scintillation Spectrometer Experiment (OSSE) for the Gamma Ray Observatory utilizes four actively-shielded NaI(Tl)-CsI(Na) phoswich detectors to provide gamma-ray line and continuum detection capability in the 0.05 - 10 MeV energy range. Additional gamma-ray and neutron detection is achieved above 10 MeV. The detectors have $3.8^\circ \times 11.4^\circ$ (FWHM) fields-of-view defined by tungsten collimators. Each detector has an independent, single-axis orientation system which permits offset pointing from the spacecraft Z-axis for background measurements and multi-target observations. The instrument and its capabilities will be described.

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INTRODUCTION

The Oriented Scintillation Spectrometer Experiment (OSSE) is one of four experiments on NASA's Gamma Ray Observatory (GRO) satellite. GRO, as one of NASA's Great Observatories, will provide coordinated observations which cover six decades of energy in the gamma-ray range. OSSE has been designed to undertake comprehensive gamma-ray observations of astrophysical sources in the 0.05 to 10 MeV energy range. The instrument includes secondary capabilities for gamma-ray and neutron observations above 10 MeV that will be of particular value for solar flare studies.

OSSE's observations will address a broad range of objectives in gamma ray astronomy, including

1. a search for evidence of heavy element nucleosynthesis through observation of radioactivity in supernova remnants,
2. a search for the power source in novae from observations of the associated radioactivity,

[1]E. O. Hulburt Center for Space Research, Naval Research Lab., Washington DC
[2]Northwestern University, Evanston, IL $> N00173-85-C-2501$
[3]Universities Space Research Association, Washington DC
[4]Applied Research Corporation, Washington DC
[5]Clemson University, Clemson, SC
[6]Royal Aerospace Establishment, Farnborough, England

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3. the study of binary systems containing neutron stars and black holes,
4. the study of pulsed and steady-state emissions from pulsars,
5. the study the diffuse emissions from the galactic plane and the galactic center regions,
6. the study of the energy source of active galactic nuclei,
7. the study of the intensity of low-energy cosmic rays and the matter density in the interstellar medium, and
8. the study of gamma-ray and neutron emissions from solar flares.

The details of the OSSE scientific objectives and plans are described elsewhere (Kurfess *et al.* 1989). In this paper we present a description of the OSSE instrument, its capabilities, and the planned modes of operation.

The OSSE experiment (Figure 1) utilizes four identical detector systems based on large area NaI(Tl)-CsI(Na) phoswich detectors. The use of NaI(Tl) scintillation crystals provides the technology for large area, high sensitivity detectors that are optimized for line and continuum measurements in the low-energy gamma-ray range. The OSSE sensitivity is achieved through offset-pointed background measurements on a time scale short with respect to the expected orbital background variations. This offset pointing is provided by an orientation control system which is integral to the OSSE instrument. Each detector is mounted in an independent elevation gimbal which provides 192 degrees of rotation capability about the spacecraft's Y-axis. The OSSE detectors are nominally co-aligned with the other pointed GRO instruments, EGRET and COMPTEL, providing coordinated gamma-ray observations of specific targets. The BATSE instrument on GRO views the entire sky. The independent pointing of the OSSE detectors also permits targeting of secondary or transient sources such as the Sun with little impact on spacecraft (S/C) orientation. The detectors are controlled by a central electronics unit which coordinates the orientation of the detectors, collects and formats the spectral and timing data from the detectors, and provides the power, command and data interface with the GRO spacecraft. A thermal shield consisting of support structure and multi-layer insulation covers the experiment for passive thermal control. The characteristics of the OSSE instrument are summarized in Table 1.

OSSE DETECTOR

Each of OSSE's four detectors operates, to a large degree, as an independent experiment. They have independent electronic systems and pointing systems. The synchronization of the four detectors is provided by the central electronics which provides the data acquisition timing and coordination of the pointing directions. Figure 2 displays the major components of one of the OSSE detectors. The principal element of the detector system is a 13-inch diameter by 7-inch thick NaI(Tl)-CsI(Na) phoswich scintillation crystal detector. This phoswich is enclosed in an annular shield of NaI(Tl) scintillation crystals which provides active anticoincidence for gamma-ray interactions in the phoswich. The annular shield also encloses a tungsten slat collimator which defines the gamma-ray aperture of the phoswich detector. A plastic scintillation detector covers the aperture for charged particle rejection. The phoswich, annular shield and associated photomultiplier tubes are completely enclosed in a mu-metal magnetic shield.

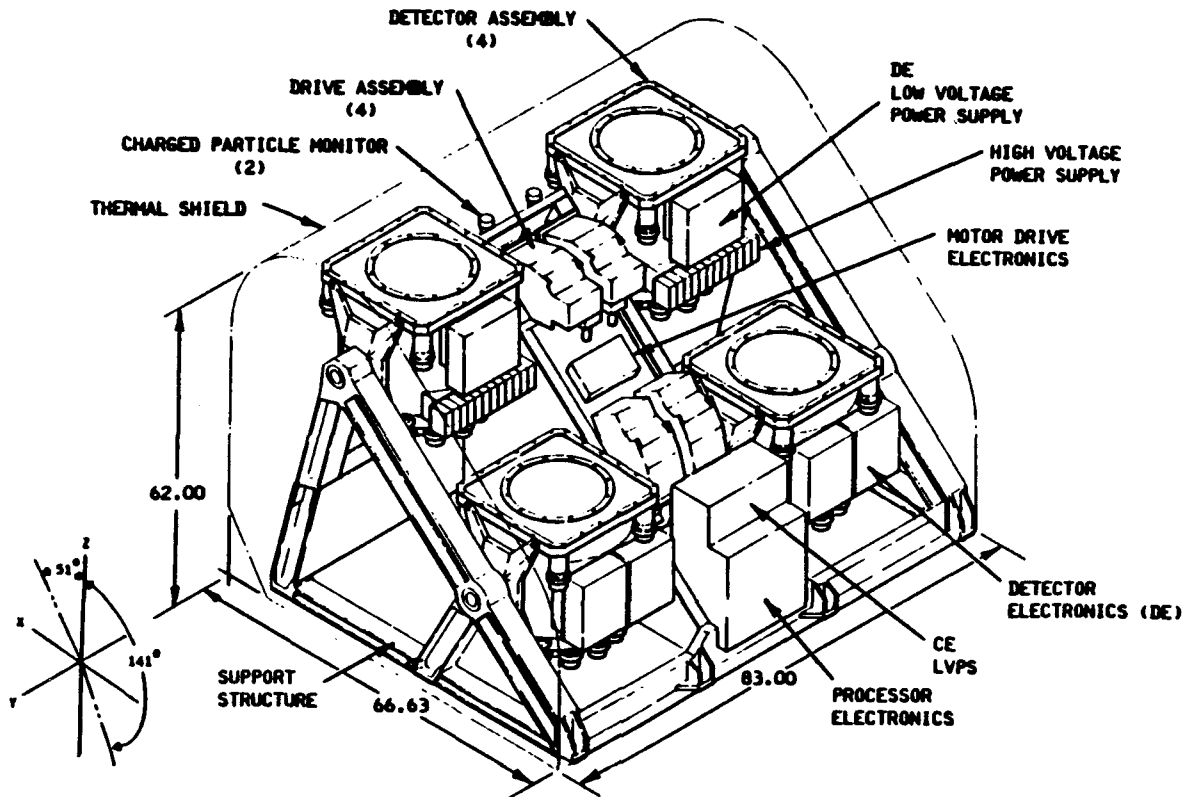# ORIENTED SCINTILLATION SPECTROMETER EXPERIMENT

Figure 1. The Oriented Scintillation Spectrometer Experiment (OSSE)

1.   Phoswich Detector

The 13-inch diameter phoswich detector consists of a 4-inch thick NaI(Tl) crystal optically coupled to a 3-inch thick CsI(Na) crystal. The phoswich is viewed from the CsI face by seven 3.5-inch photomultiplier tubes (PMTs). In this configuration, the CsI portion of the phoswich acts as anticoincidence shielding for the NaI portion. The detector event processing electronics incorporates pulse-shape analysis for the discrimination of events occurring in the NaI crystal from those occurring in the CsI. This discrimination utilizes the differing scintillation decay time constants of NaI and CsI.

Energy losses in the phoswich are processed by three separate pulse-height and pulse-shape analysis systems covering the energy ranges: 1) 0.05 - 1.5 MeV, 2) 1 - 10 MeV, and 3) >10 MeV (nominally 10 - 250 MeV). The two lower ranges are derived from the summed output of the anodes of the seven 3.5-inch PMTs (RCA 83013F). The highest range is derived from the summed output of the eighth dynodes of these PMTs. The pulse-shape discrimination in the highest range is also used to separate neutron and gamma-ray energy losses in the NaI portion of the phoswich. This discrimination utilizes the differing time characteristics of the secondaries produced by these interactions (Share et al. 1978). Gamma-ray event validation in all three ranges includes

1. anticoincidence with energy losses in the NaI annular shield,
2. anticoincidence with aperture charged particle detector, and
3. pulse shape qualification as energy loss in the NaI crystal.

The pulse-shape analysis utilizes rise-time to zero-crossing time measurement on the bipolar-shaped signals from the PMTs. Validated events are digitized by 256-channel Wilkinson run-down analog-to-digital converters. Both pulse height (energy loss) and pulse shape are digitized. The digitized pulse shapes are utilized for further event qualification in the form of energy-dependent pulse-shape discrimination. This energy-dependent discrimination permits the optimum rejection of events with partial CsI energy losses (e.g. Compton scattering) at each energy. Fully qualified events are presented to the spectral accumulation and pulsar analysis circuits described below.

Optimum spectral resolution in the phoswich detector requires precise gain adjustment of the seven PMTs viewing the phoswich. This gain balance among the tubes is preserved in orbit by individual control of the high voltage to each PMT. The high voltage control is provided by an automatic gain control (AGC) system utilizing a light emitting diode (LED). The light flashes from the LED as seen by each PMT are measured against a reference and the resulting error signal is used to adjust the high voltage power supply for that PMT. A secondary control system utilizing a PIN diode also measures the light flashes from the LED but corrects the amplitude of the LED flash. Thus, this secondary control provides stable LED output for the PMT gain measurements.
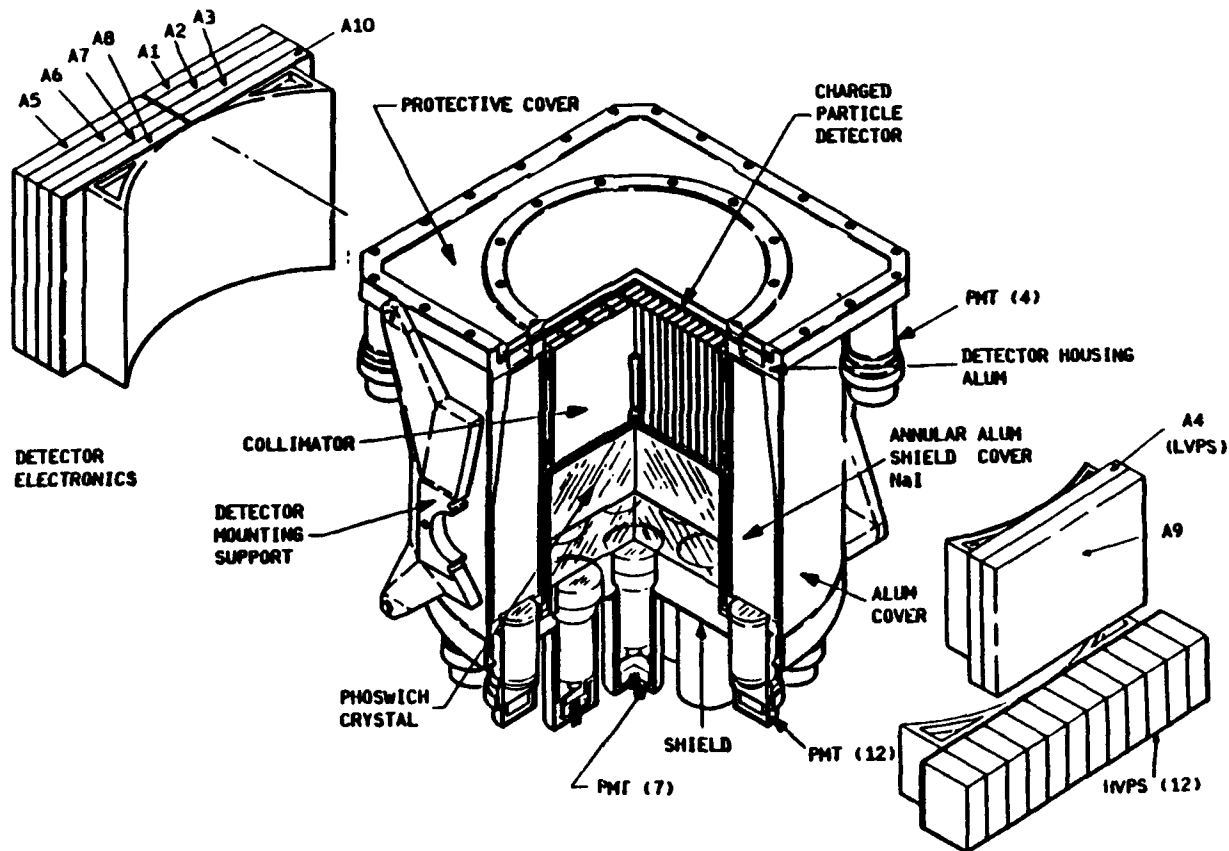

Figure 2. The OSSE Detector Configuration

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The specific task of the AGC system is to preserve the relative gain of the seven PMTs viewing the phoswich with respect to temperature and magnetic field variations. Its ability to preserve the absolute gain of the phoswich is limited by the temperature dependence of the light output from the scintillation crystals and the temperature dependence of the spectral response of the photomultiplier tubes. An absolute gain stability of 0.20% per degree C has been demonstrated in calibrations. Due to the very small anticipated detector temperature variation on orbital timescales (<0.5 °C), the absolute gain of the OSSE phoswich is expected to be stable to within 0.1%.

Since offset pointing is used to measure the OSSE background (see below), the varying magnetic field orientations for the target and background pointings could produce differing gains for the measurements. The OSSE design has addressed this magnetic field sensitivity of the gain of the phoswich photomultiplier tubes by incorporating, in addition to the AGC system, a multiple co-netic shield design. Each OSSE PMT is individually housed in a mumetal shield, and an additional mumetal shield completely encloses the phoswich, annular shield and their associated phototubes. This shield achieves a reduction of the external magnetic field by a factor of 50 as seen by the PMTs.

The absolute gain of the phoswich is monitored and reported utilizing an internal ^{60}Co radioactive source. A ^{60}Co-doped plastic scintillation detector and associated 0.75-inch photomultiplier tube is positioned within the tungsten collimator with the ^{60}Co source nearest the phoswich. This configuration provides gamma-ray calibration lines at 1.17 MeV, 1.33 MeV and the sum peak at 2.5 MeV. By using the coincident β energy loss in the plastic scintillator as a calibration event tag, high signal-to-noise calibration spectra are obtained with relatively weak (~4 nanocurie) radioactive sources. These ^{60}Co calibration spectra are routinely collected and transmitted in the OSSE data.

2. Annular Shield

The NaI(Tl) annular shield enclosing the phoswich is 3.35 inches thick and 13.75 inches long. It is divided into four optically-isolated quadrants or segments, each viewed by three 2-inch photomultipliers (RCA S83019F). Energy losses above 30 keV are detected and utilized for rejection of coincident energy losses in the phoswich. Three shield anticoincidence discrimination signals are used in the event processing:

LOW: A 100 keV threshold (programmable from 30 - 470 keV) is used as the low level discriminator for the lowest two phoswich energy ranges,
MED: A 1.2 MeV threshold is used as the low level discriminator for the highest phoswich energy range, and
  HI: An 8 MeV threshold is uses as the upper level discriminator for all phoswich ranges and triggers a longer rejection pulse for possible cosmic ray overloads.

Annular shield energy losses in the 30 keV to 8 MeV range are pulse height analyzed as part of the diagnostic calibration analysis system discussed below. The good spectral resolution of the shield segments (10.5% at 0.66 MeV) permit the use of shield spectra in the study of solar flares and possibly gamma ray bursts. The low level discriminator event rates from the shields are processed by the OSSE central electronics for the detection and capture of

gamma ray bursts (see below). This gamma ray burst trigger operates independently from the trigger provided by the BATSE instrument (Fishman et al. 1989).

3. Charged Particle Detector

The charged particle detector consists of a 20-inch square by 0.25-inch thick plastic scintillator (Bicron BC408) closing the aperture of the phoswich detector. It is viewed by four 2-inch photomultipliers (RCA S830019E). Energy losses above a nominal threshold of 200 keV trigger rejection of coincident energy losses in the phoswich.

4. Tungsten Collimator

The aperture of the OSSE detector is defined by a tungsten slat collimator which provides a rectangular field of view of 3.8 x 11.4 degrees. The collimators were machined from 13-inch diameter by 7.25-inch thick scintered ingots of tungsten alloy, to provide 0.54" x 1.58" aperture cells. The tungsten slats are 0.075" thick in the 3.8° direction and 0.113" thick in the 11.4° direction. As seen in Figure 3, the high stopping power of tungsten provides collimation which opens only slightly at higher energies.
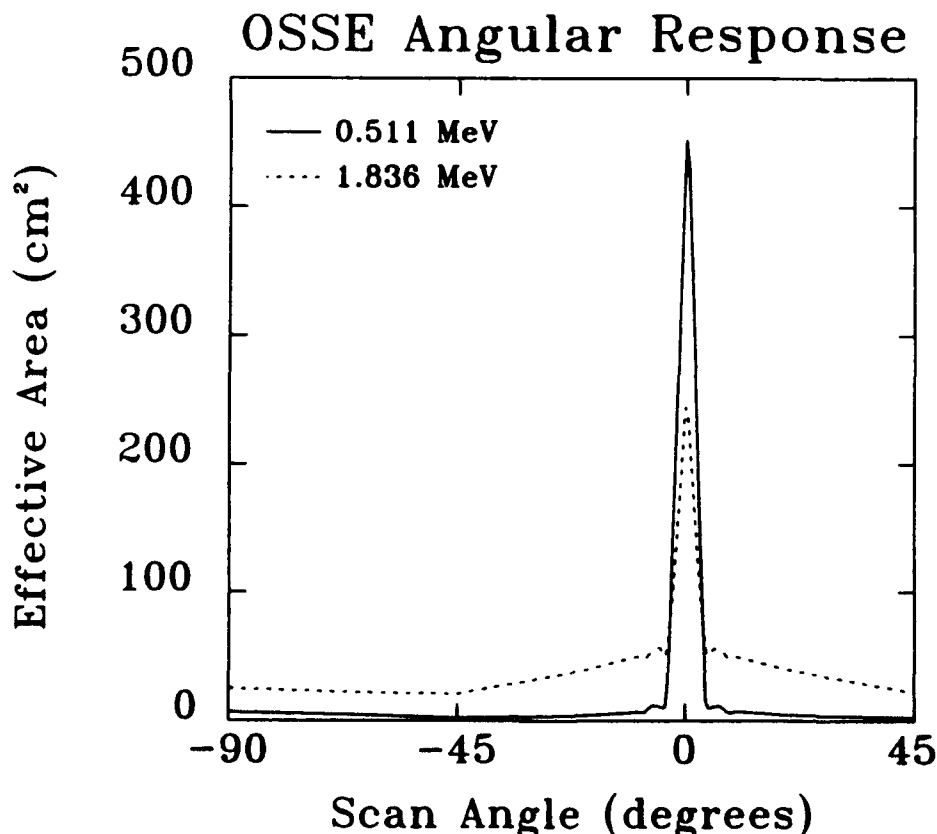

Figure 3. Measured OSSE Angular Response Function for Detector 3. The photopeak effective area at two energies is plotted as a function of collimator scan (offset) angle.

Table 1.
OSSE SUMMARY

Detectors

Type:	4 identical NaI-CsI phoswiches, actively-shielded, passively collimated
Aperture Area (total):	2620 cm^2 1920 cm^2 at 0.511 MeV
Field-of-View:	3.8° x 11.4° FWHM
Energy Resolution:	8.2% at 0.661 MeV 3.8% at 6.13 MeV
Time Resolution:	4 sec in normal mode 0.125 msec in pulsar mode 4 msec in burst mode

Experiment Sensitivities (10^6 sec)

0.1 - 10 MeV Line γs	~ 2 - 5 x 10^{-5} γ cm^{-2}s^{-1}
0.1 - 1 MeV Continuum	0.005 x Crab
1 - 10 MeV Continuum	0.05 x Crab
Gamma Ray Bursts	1 x 10^{-7} erg cm^{-2}
Solar Flare Line γs (10^3 sec flare)	1 x 10^{-3} γ cm^{-2}s^{-1}
Solar Flare Neutrons (>10 MeV)	5 x 10^{-3} n cm^{-2}s^{-1}

Pointing System

Type:	Independent Single Axis
Range:	192° about the S/C Y-axis
Accuracy:	6 arc minutes
Speed:	2°/sec (max)

GRO - OSSE Interface

Weight:	1820 kg
Power:	192 watts
Telemetry:	6492 bits/sec

OSSE DATA TYPES

The overall operation of the OSSE instrument is controlled by the central electronics processing unit. This computer system, based on a Texas Instruments 9989 microprocessor, controls the acquisition and formatting of the data from the detectors into the OSSE telemetry stream and coordinates the detector positions with the data collection. OSSE is allocated approximately 6.5 kilobits per second of the GRO 32 kilobit per second telemetry stream. This allocation is provided in the form of an OSSE telemetry "packet" of 1692 bytes which is transmitted every 2.048 seconds. The contents and format of the OSSE telemetry packet is a function of the OSSE operating mode and telemetry format. OSSE can operate in any of 18 pre-programmed telemetry formats or can have new formats designed and up-loaded from mission control into the central electronics memory. These telemetry formats adjust the telemetry allocation to the various OSSE data types to optimize the OSSE telemetry data for the scientific objectives of a particular GRO observation period. These formats vary the time resolution and event rate capabilities of the detectors' gamma-ray measurements. The OSSE data types are described below.

1. Spectral Memory Data

The primary data from the OSSE instrument consist of time-averaged energy loss spectra from the individual detectors. Each detector accumulates separate energy loss spectra from the validated gamma-ray events in each of the three energy ranges. The time interval (spectrum acquisition cycle time, T_{SAC}) for these accumulations is a function of the overall operating mode of the OSSE experiment and is typically 4 seconds. The acquisition cycle time is controlled by the OSSE central electronics which selects the T_{SAC} interval based on the OSSE telemetry format. Acquisition times in the range between 2 seconds and 32 seconds are available. The detectors' accumulation memories are double buffered so that accumulation occurs in one memory while the other memory is transmitted to the telemetry formatter. The accumulation memories can support a maximum of 4095 events per spectral channel per T_{SAC}.

Gamma-ray events for the two lowest phoswich energy ranges (0.05 - 1.5 MeV and 1 - 10 MeV) are separately accumulated into 256 channel spectra. These energy loss spectra have uniform channel widths of ~6 keV and ~40 keV, respectively. The highest phoswich energy range (>10 MeV) is processed to discriminate gamma-ray and neutron events. These gamma-ray and neutron events are then separately accumulated into 16 channel spectra. These energy loss spectra have uniform channel widths of ~16 MeV.

The central electronics collects these four spectra from each of the four detectors and applies any specified compression for transmission in the OSSE telemetry packet. A complete set of housekeeping data is also obtained from each detector on the same time scale as the spectral memory data. This includes live time and rate monitors, command state verification, analog voltages and temperature monitors.

2. Pulsar Data

High time resolution gamma-ray data is provided in the OSSE pulsar data modes. Validated gamma-ray events in each of the detectors are transmitted to the central electronics pulsar processing software for inclusion in the OSSE

telemetry stream. The pulsar data modes permit transmission of time-tagged gamma-ray energy losses in the OSSE packet. However, the entire event stream from the detectors can not be accommodated in the OSSE packet. Consequently, the pulsar processing includes considerable event selection and compression for telemetry formatting. The pulsar processing permits the definition of up to eight energy bands to be included in the transmitted pulsar data. These energy bands, as well as the rest of the pulsar data collection configuration, can be defined by OSSE mission operations activities and uploaded into the experiment via command. The pulsar data can therefore be optimized to the specific observing target while limiting the event rate to that which can be handled in the OSSE telemetry.

Gamma-ray events qualified as being in one of these eight energy bands are then processed in one of two modes:

1. event-by-event mode, where selected events are time-tagged and both energy loss and arrival time of the event are transmitted in the telemetry, or
2. rate mode, where high time resolution rate samples are taken in each of the eight energy bands.

The event-by-event mode of pulsar data provides the highest time resolution for the study of fast pulsars. This mode time-tags events accurate to 0.125 milliseconds at its highest resolution. These arrival times, detector identifications, and encoded energy losses are transmitted in the event-by-event mode. Depending on the OSSE telemetry format, a maximum of ~290 events per second is supported in the event-by-event pulsar mode.

The pulsar rate mode can accommodate a much higher event rate but at the sacrifice of spectral resolution. This mode records the number of events in each of the defined energy bands at a specified sample frequency. The highest sample rate in this mode provides a resolution of 4 milliseconds. Sample times from 4 msec to 512 msec can be selected.

3. Gamma Ray Burst Data

OSSE includes a gamma ray burst capture capability which is based on the measurement of the gamma-ray event rates in the NaI annular shields. These event rates are sampled by the OSSE central electronics on a selectable time scale of from 4 msec to 32 msec. A gamma ray burst trigger signal, either from BATSE or from internal processing, activates the storage of the next ~4000 samples in a burst memory. A selectable fraction of this memory preserves the rate samples prior to the trigger. With coarser time resolution (~1 sec), rate samples from the individual NaI shield quadrants are available which can be used to identify the direction of the gamma ray burst. Approximately 5 minutes are required to transmit the burst history in the OSSE telemetry packet.

The OSSE internal burst trigger monitors the annular shield rate samples for successive samples above a specified event rate as the indication of a gamma ray burst. The BATSE Burst Trigger Signal will be the primary burst trigger signal for OSSE since it incorporates more sophisticated trigger detection and a burst direction measurement which will be able to identify possible solar flares (Fishman et al. 1989). As discussed below, this ability to react to solar flares will significantly enhance the OSSE science.

Part of the OSSE response to a burst trigger signal permits the activation of an altered science data collection mode for the OSSE instrument which includes a change in the detector positions and/or change in the telemetry format for data collection. Thus, OSSE can be re-configured in response to a gamma ray burst without intervention by controllers on the ground.

4. Diagnostic and Calibration Data

In addition to the ^{60}Co absolute gain calibration sources described above, the OSSE instrument includes several performance monitoring capabilities which permit verification of and subsequently, by command, optimization of the operational performance of the various detector components. These include:

1. Pulse-shape discrimination efficiency monitoring. The ability to monitor the performance of the phoswich pulse shape analysis provides optimum selection of the discrimination levels for background rejection and is also required in the instrument response model for correction of measured energy loss spectra into incident photon spectra. This diagnostic data is provided in the form of two-parameter spectra - phoswich energy loss vs. pulse shape - which are collected by the central electronics from event streams transmitted by the detectors. The central electronics collects data from one detector at a time and transmits it at a low rate. A typical configuration might require 20 minutes to sample the two parameter spectra from all three energy ranges from all detectors. Analysis of these spectra can produce corrections to the energy-dependent shape discrimination tables used by the detector event qualification as described above. These corrections are transferred to the instrument by command.

2. Anticoincidence system performance. Each of the segments of the NaI annular shields and the charged particle detectors which cover the apertures have ^{241}Am calibration sources imbedded in the detector. These calibration sources consist of small ^{241}Am-doped NaI crystals which provide calibrated light flashes from the α-particle interaction in the NaI crystal. A calibration pulse height analyzer cycles among these detector elements collecting energy loss spectra. These spectra permit verification of the gain calibration of the element and the setting of the anticoincidence discrimination level, all of which can be changed by command.

3. Charged particle background and SAA monitoring. The OSSE instrument includes a separate charged particle monitor detector. This 0.75-inch diameter plastic scintillation detector is enclosed in a passive shield of ~3 gm/cm^{-2} of aluminum and viewed by a 0.75-inch PMT. The event rates in this detector provide a monitor of the high energy charged particle environment for OSSE. Additionally, it provides a detection of the S/C entry into the South Atlantic Anomaly (SAA) where the high fluxes of charged particles can potentially degrade the performance and lifetime of the other OSSE detectors. The S/C is designed to turn off the OSSE detectors during traversals of the SAA; this charged particle monitor, however, remains on to provide integral charged particle dose monitoring for background modeling.

OSSE OPERATING MODES

The GRO spacecraft provides a three-axis stabilized platform from which the GRO instruments will make their observations (see Figure 4). The 180° rotation of the GRO solar arrays about the Y-axis permits observation of any point in the sky at any time of the year. The instruments (with the exception of BATSE which is designed to view the complete sky) are aligned with the center of their fields-of-view along the spacecraft Z-axis. The nominal GRO observing plan calls for two week observations at each selected Z-axis direction. Since the OSSE field-of-view is much smaller than those of the other GRO instruments, the S/C Z-axis will generally be pointed directly at an OSSE candidate source. These candidate sources are developed from lists of interesting targets as identified by the various OSSE scientific areas of interest (see Kurfess *et al.* 1989) and as identified by previous measurements at gamma-ray and other wavelengths.
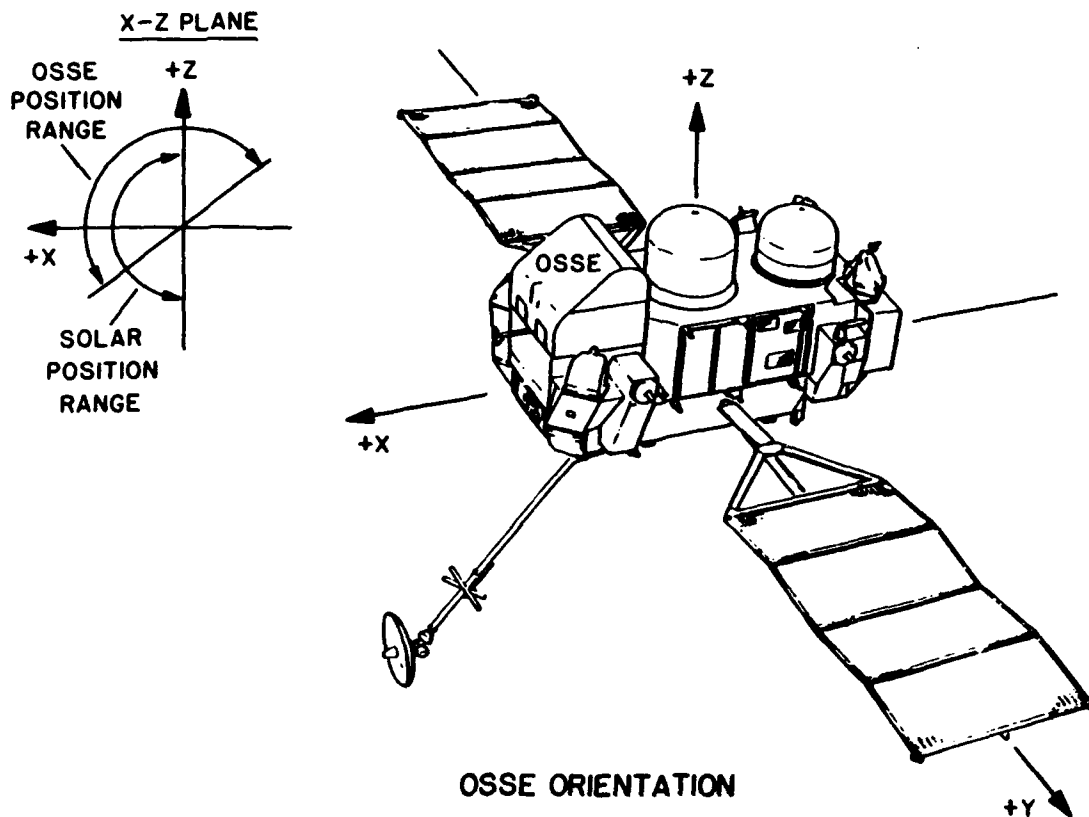

Figure 4. The GRO Spacecraft and OSSE's Orientation Capability

The OSSE instrument achieves its sensitivity through offset-pointed background measurements. OSSE's pointing control system is used to remove a particular source target from the field of view of the detectors to sample the detector background. These alternating target and background measurements occur on time scales which are fast, typically 2 minutes, relative to the expected orbital background variations. The difference in the energy loss spectra while viewing the source target and while viewing the backgrounds represents the spectrum of the source. Each of the detectors is controlled independently by the OSSE central electronics and has its own observing sequence. Nominal observing sequences will have the detector motions phased so that two of them will be viewing the source while the other two will be measuring the background.

The tungsten collimators are installed in the detectors so that OSSE detector motion scans the source with the collimator's 3.8° (FWHM) field of view. As seen in Figure 3, a background offset of ~5° provides optimum modulation of the source contribution. This background offset, however, is programmable so that alternate background offsets can be selected in source-confused regions or for other scientific reasons. The nominal observing sequence observes the background on both sides of the source target. The average of these two backgrounds will generally be used in the data analysis as the "background" for the source observation. This technique minimizes the systematic effects of modulation of gamma-ray background local to the spacecraft. A typical detector observing sequence might consist of continuous repetition of the following sequence:

1. observe the source direction for 2 minutes,
2. move to a background position ~5° counter-clockwise from the source and observe for 2 minutes,
3. return to the source direction and observe for 2 minutes, and
4. move to a background position ~5° clockwise from the source and observe for 2 minutes.

The motion occurs at a fixed rate of 2° per second. These observing programs can define sequences of up to 8 source and background offsets which can be used for source positioning or more complicated background modeling.

While OSSE will nominally observe along the S/C Z-axis, the detector's orientation control systems provide 192° of rotation about the S/C Y-axis (see Figure 4) which permits selection of candidate sources away from the Z-axis direction. In the 90 degrees between the S/C Z and X axes, all four detectors can be used for observations. Outside this range, the upper pair and lower pair of detectors begin to intrude into each others' fields of view. In that situation, the upper pair of detectors can be programmed to view one source and the lower pair can view another, independent target.

In general, the GRO viewing program selects a Z-axis viewing direction for a two week interval. The orientation of the S/C about this direction (the direction of the X-axis) is selected based on solar input to the S/C solar arrays and the OSSE candidate targets away from the Z-axis which would be accessible with the OSSE orientation capability. The sizing of the solar arrays and solar array shadowing considerations permit the Sun to be as far as ~42° outside the X-Z plane (ie. ~42° from the normal to the solar arrays). This is the permissible solar offset angle at the start of the GRO mission; it is expected to reduce in size as the solar arrays age and lose efficiency. This 42° solar offset provides OSSE with considerable flexibility in the selection of targets away from the Z-axis.

Secondary Source Opportunities

The GRO orientation with respect to the celestial sphere is defined by the center of the GRO instruments' field of view (S/C Z-axis direction) and by the position of the Sun which constrains the yaw (rotation) of the S/C about the Z-axis. Consequently, the region of the sky which is accessible by OSSE's detector motion is constrained by the position of the Sun and the maximum offset from the S/C solar array normal. By considering the seasonal ordering of the GRO Z-axis viewing directions, OSSE can select secondary viewing directions which contain interesting targets well away from the Z-axis. In particular, finding a second target at an OSSE orientation near the X-axis, in addition to the primary target at the Z-axis, provides the possibility of a secondary target which OSSE can view at times in the orbit when the primary, Z-axis, target is occulted by the earth. Thus, OSSE can make good use of the Z-axis earth occultation periods by viewing a secondary target. By selection of the S/C orientation at the start of a two week observation, OSSE can move its detectors between the primary, Z-axis, source and the secondary target each orbit without reorientation of the S/C (see Figure 5).

SUN

PSR 0833-45

PSR 0833-45 MODE
(Continuous Pointing)

GALACTIC
CENTER

GALACTIC
CENTER MODE
(Offset Pointing)

Source
Transition

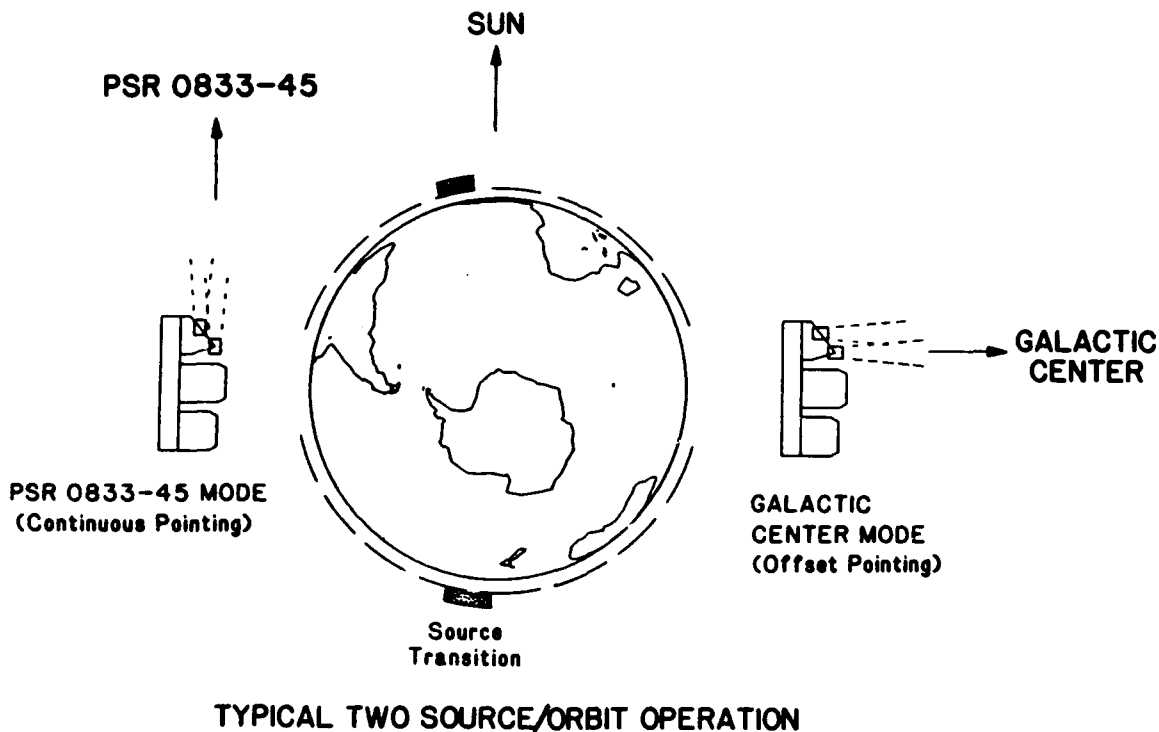TYPICAL TWO SOURCE/ORBIT OPERATION

Figure 5. OSSE's Two Source per Orbit Operation. During earth occultation of the primary target (the Galactic Center in this example), OSSE moves to a secondary target (PSR 0833-45). S/C pointing is not affected.

This switching between the primary and secondary viewing programs on an orbital timescale is controlled by timed commands which are stored in the S/C computer. The times of the commands are determined by OSSE mission planning based on the viewing angles to the two targets. A single command is required to activate one of the viewing programs. OSSE supports four different viewing programs which can be loaded by command from the ground.

The major activity of the GRO/OSSE observing program planning is finding the optimum selection of primary-secondary target pairs which provide the best use of the OSSE observing time. Figure 6 is an example of the planning process which shows (in galactic coordinates) the candidate OSSE secondary targets which are available for a December observation of 3C273 at the Z-axis. In December the Sun appears near the Galactic Center so that the solar constraints permit access to sources in the galactic center direction. In the figure, OSSE's orientation capability enscribes great circle arcs from the primary source, 3C273, toward the galactic center. The triangular shaped regions outline the bounds of these great circle arcs permitted by the solar array offset constraint of ~42°. A region of 30° wide located approximately 90° from the Z-axis is identified by the two lines perpendicular to the arcs and identifies the principal candidates for secondary targets. The selection of one of these candidate secondary sources then fixes the S/C X-Z plane and hence the solar offset angle.
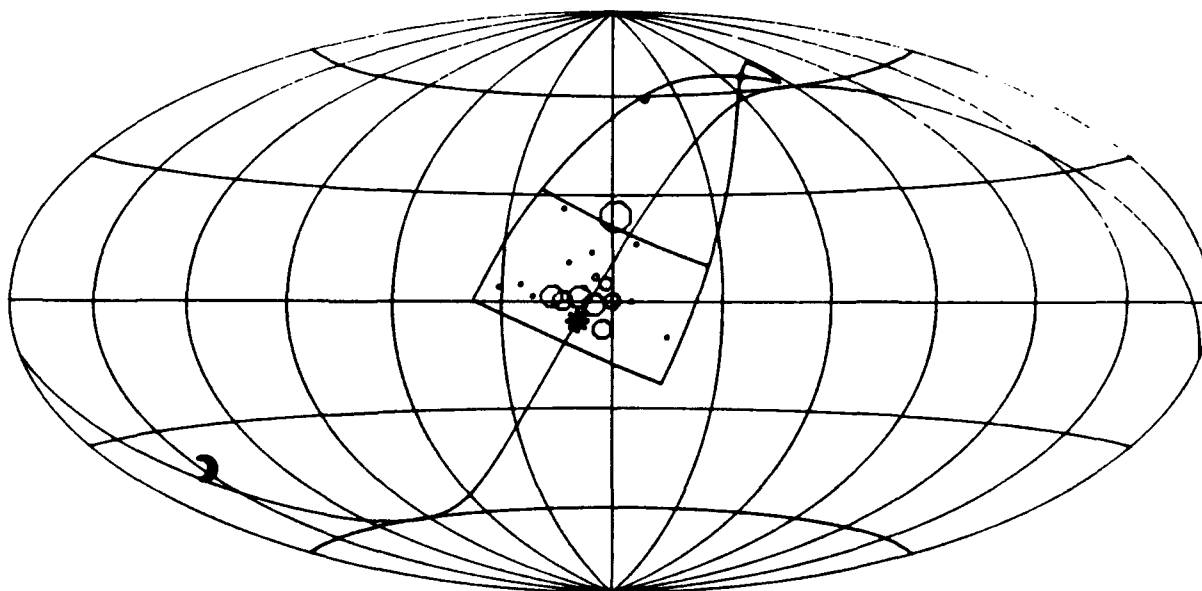

Figure 6. OSSE Secondary Target Selection. The accessible OSSE candidate sources displayed in galactic coordinates for a December observation of 3C273 as primary target. Octagonal symbols indicate source positions with approximate X-ray intensity represented by symbol size. The sun and moon positions are indicated by star and crescent symbols.

Solar Viewing

As shown in Figure 4, OSSE is situated on the +X end of the GRO space-craft. Solar array articulation constraints and spacecraft thermal constraints require the Sun to be in the +X hemisphere. Consequently, OSSE's orientation capability, discussed above, often permits direct viewing of the Sun even when the other instruments are observing in some other direction. Thus, the Sun is often a candidate secondary target for OSSE viewing. As indicated in Figure 4, the OSSE orientation range and solar array range do not exactly coincide but have a 141° region of overlap.

This ability to select a GRO viewing program which enables OSSE to move from the Z-axis target to the Sun without re-orientation of the S/C provides a significant capability for reaction to solar flares. Additionally, BATSE has the ability to detect and identify solar flares and signal OSSE that a possible flare has begun. OSSE can react to the BATSE solar flare trigger by initiation of a new viewing program and telemetry format which moves all detectors to solar viewing.

BATSE nominally takes 8 seconds to identify the transient event as coming from the solar direction. This is done by comparison of transient event responses in the solar-viewing BATSE detectors (see Fishman *et al.*, 1989). The response time to a solar flare would be ~60 seconds to re-orient the detectors and requires no contact with the ground controllers.

OSSE can also react to a BATSE solar trigger by changing the data collection mode of the calibration system, providing the capability of successively accumulating spectra from the OSSE annular shield segments with a time resolution of up to ~4 seconds. This capability can provide modest spectral and temporal resolution data on solar flares without re-orientation of the OSSE detectors.

OSSE CALIBRATION AND PERFORMANCE

Extensive calibration and testing were performed in order to characterize the OSSE instrument performance. These calibrations consisted of tests performed on both the prototype engineering detector (an exact copy of a single flight detector) and the entire OSSE flight instrument, and included the acquisition of over 10,000 hours of data. The results of these calibrations will be used to validate the OSSE Monte Carlo simulation and to produce a detailed instrument response model. The response model will be used during the data analysis to extract the incident gamma-ray spectrum from an observed counting rate spectrum. The calibration tests included:

1. Detailed measurements of the instrument efficiency and angular response using radioactive sources providing gamma-ray lines from 0.06 to 6.1 MeV. The detector efficiency and spectral response was measured under various instrument anticoincidence configurations and at several temperatures within the expected on-orbit temperature range. The detector angular response was measured at over 2000 positions for the engineering detector and at nearly 400 positions for the OSSE flight instrument.

2. Measurements of the engineering detector neutron response using a ^{7}Li(p,n) neutron source at the Indiana University Cyclotron Facility. Efficiency and angular response measurements were performed for beam energies in the 30 - 200 MeV energy range. Measurements to characterize the discrimination between neutrons and gamma-rays for these energies were also performed.

3. Measurements of the engineering detector response to high energy gamma-rays. Gamma-ray lines over the energy range 4.4 - 19.8 MeV were produced by using low energy protons from a Van de Graaf accelerator to illuminate targets made of fluorine, lithium, boron, aluminum and tritium. Both energy loss and angular response of the engineering detector were measured.

4. Background measurements performed during a balloon flight of the engineering detector on May 17, 1988, from Alice Springs, Australia. This flight provided a cosmic-ray environment similar to that expected in the GRO orbit. The data taken during the balloon flight have been used to estimate the OSSE on-orbit sensitivity and have also provided useful information on the effects of cosmic-ray interactions and neutron activation on the detector performance.

Figure 7 summarizes the results of some of these calibrations in the display of the expected OSSE sensitivity to celestial line gamma-ray emissions for a 10^6 second observation. This sensitivity was estimated using the results from the efficiency, angular response, and spectral resolution measurements, as well as the background estimates obtained from the balloon flight.
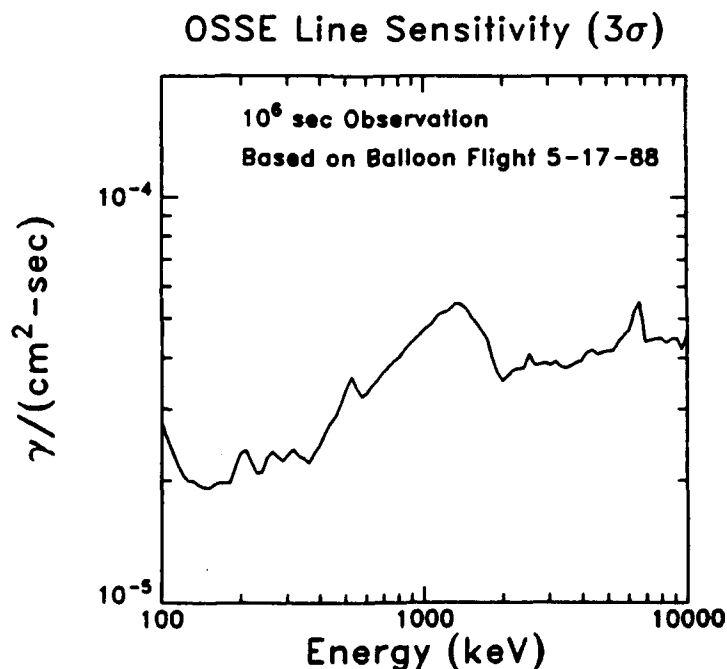
OSSE Line Sensitivity (3σ)

Figure 7. OSSE Sensitivity for the detection of line gamma rays.

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